LPS28DFW digital pressure sensor: guidelines for system integration

Introduction

The purpose of this application note is to introduce guidelines for the system and hardware integration of the LPS28DFW water-resistant pressure sensor in the final application.

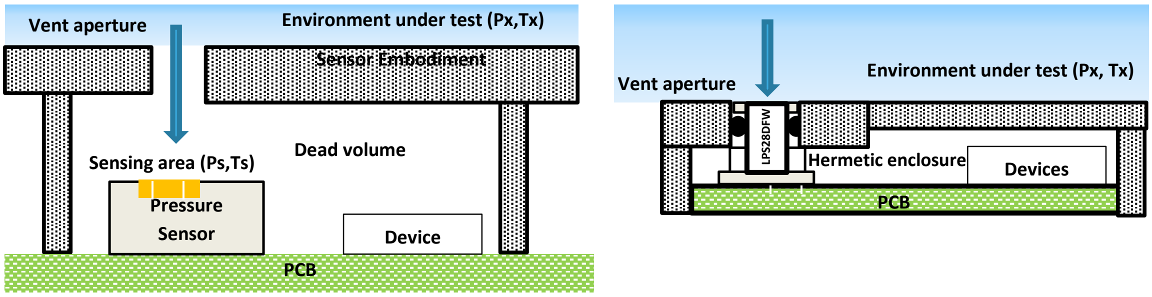
This document does not modify the content of the official datasheet. Refer to the datasheet for parameter specifications.

1 System integration

The integration of the LPS28DFW pressure sensor in application systems such as portable devices (PDs) like smartphones, wearable devices, weather stations, or industrial tools shall be implemented without compromising sensor performance. System integration can be done by looking at the main mechanical and geometrical parameters and the factors that influence the sensor performance and thus optimizing those.

The typical sensor integration scenario for pressure sensors is described in Figure 1 (a) "Pressure sensor standard integration" where the housing of the sensor has to be designed in order to get as much equivalence as possible between (Px, Tx), the pressure and temperature conditions of the environment under test, and (Ps, Ts) that represent the conditions around the sensor sensing area, near the air inlets.

Figure 1. Pressure sensor system integration (a) standard pressure sensor, (b) LPS28DFW water-resistant pressure sensor



(a) Pressure sensor standard integration

(b) Water-resistant pressure sensor

The LPS28DFW is featured as a water-resistant device, which means that it can be exposed to water pressure, recover, and maintain the same performance over time. In water-resistant application contexts like smartwatches and fitness devices, it is a common design practice to have the pressure sensor in communication with the external environment through one hole and to keep it isolated from the other devices placed in the hermetic enclosure by means of an appropriate cylinder-shaped housing and the use of an O-ring as indicated in Figure 1 (b). More details are given in the following paragraphs.

In order to get a reliable and consistent measurement, all the parameters involved in the mechanical design must be dimensioned to provide stability from the air or water overpressure, to get the maximum sensor exposure to the external environment, and to get the fastest response time, in terms of pressure and temperature, compatible with the required design specifications.

Any change in the environmental condition under monitoring must be reflected as a sensor-consistent measurement, as well as fast variations in pressure and temperature. Therefore, the integration design must guarantee that the environmental conditions match the sensing area conditions not only in “steady-state” (static conditions) but also in dynamic conditions.

Deviations between the conditions under test and the conditions around the sensing area are also influenced by sources of heat, like other devices close to the sensing area or the self-heating of the sensor. Changes in temperature are critical due to the fact that not only the temperature is influenced but, changes in temperature also determine pressure deviations and, as a consequence, a slower response of the system.

Based on the considerations above, the design optimization consists of determining:

- The placement of the sensor in the system
- The sensor embodiment and housing
- Protection of the sensor in the presence of a harsh environment such as dust, water, or chemical solvents using a sensor chamber

The above elements are further described in the following sections of this document.

2 Mechanical design rules

For the mechanical design, the main constraints and features to be considered are described below, to provide a set of basic rules such as good design practices for a successful integration of the sensor in the context of the final application.

2.1 Sensor placement

The placement of the sensor has a direct impact on its performance in terms of proximity to the environment, means of thermal propagation, and mechanical stress.

2.1.1 Exposure to the environment

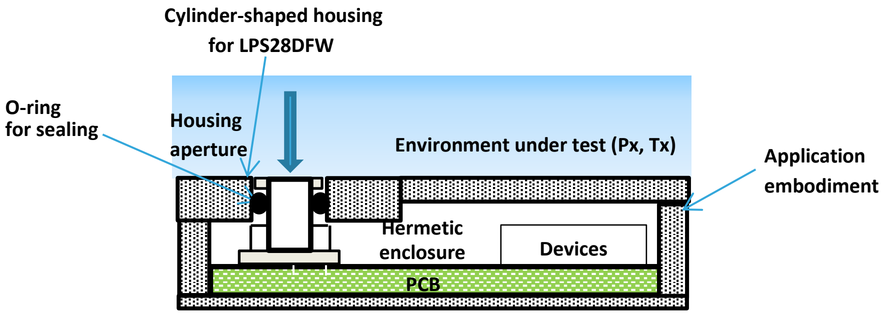
One key design rule is to maximize the exposure of the pressure sensor with the environment to identify where to measure pressure and temperature; in other words, the sensor has to be optimally placed in order to react to fast changes in environmental conditions by providing a reliable measurement following the dynamic of environmental changes.

The integration design of the pressure sensor clearly impacts the overall response time. Typically the design target is to match pressure sensor performance as given in the datasheet. The following guidelines are recommended, with reference to Figure 2. Pressure sensor integration and housing for achieving this objective:

1. Position the sensor to get the best connection with the environment under test, as close as possible to the vent aperture.
2. Large dead volume will increase the response time, with a bigger contribution to the pressure response time; therefore it is recommended to minimize the volume, trying to shape a tailored housing around the sensor geometry.
3. Vent aperture should be as large as possible.
4. The depth of the vent aperture must be minimized.

As a reference for system integration design, the following figure describes an example of the above recommendations.

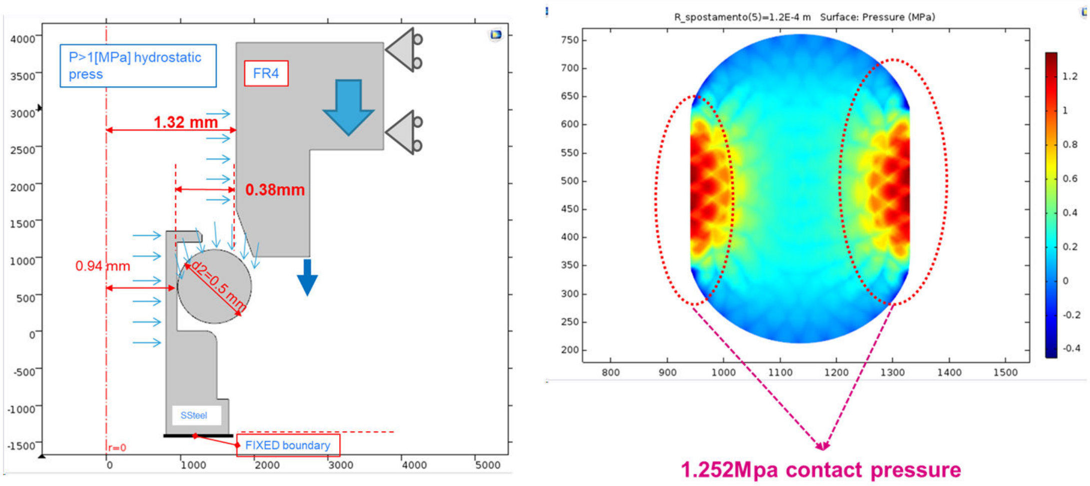
Figure 2. Pressure sensor integration and housing



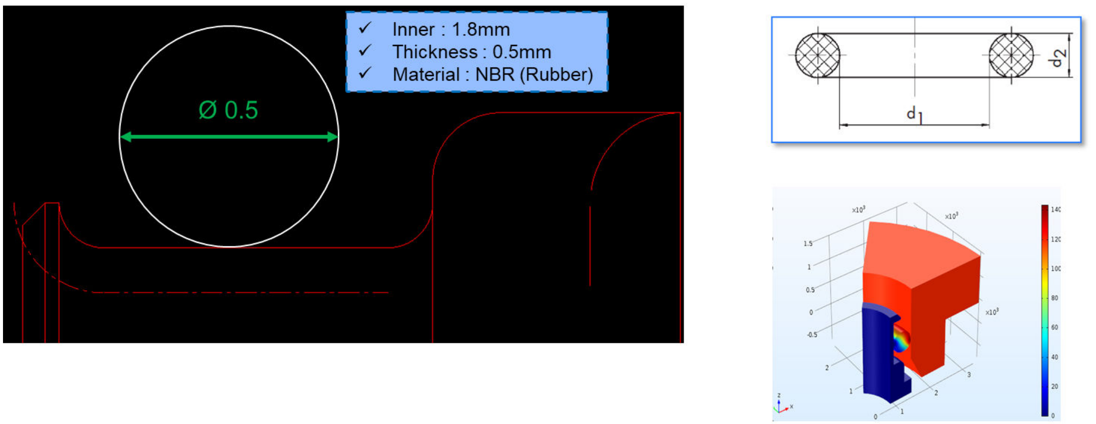
2.1.2 O-ring for sealing

In wearable and portable applications, it is necessary to add a sealing mechanism such as an O-ring in order to avoid that direct water or other liquid can reach the PCB or other areas of the customer application as depicted in Figure 2. For such applications, the LPS28DFW provides the possibility to seal and protect the embodiment by placing the O-ring at the groove location (mid part of metal lid). Simulation results show that the surface contact pressure between an O-ring of 1 mm as diameter and two contact sides (lid of LPS28DFW and plastic embodiment) is 1.25 MPa by applying the geometries in the figure illustrated below. Therefore the sealing can be guaranteed until fluidic hydrostatic pressure is less than contact pressure (i.e 10 bar (1 MPa) ≤ 1.25 MPa).

Figure 3. Groove for O-ring, simulation with O-ring applied on LPS28DFW



d1 ≥1.8mm	d2 ≤0.88mm	d1+2*d2
1.8	0.5	2.8



The thickness of the O-ring needs to be sized in order to fit the housing and to apply a sealing force for resisting to 10 bar fluidic pressure according to the device specification. The following commercial O-ring can be used as a reference, considering the LPS28DFW package dimension.

- Inner diameter: 1.8 mm
- O-ring thickness: 0.5 mm
- Material of O-ring: NBR (rubber) with 70 hardness

The selection of the O-ring depends on the geometries of the customer application, specifically the cylinder-shaped housing geometries. The information provided above about the O-ring is exclusively given as general information, it cannot be considered as qualified for any particular customer application.

2.1.3 Heat propagation

The presence of sources of heat near the sensor can deteriorate the performance by modifying pressure and temperature measurements as well as generating thermal gradients around the sensing area, affecting the correct measurement in static and dynamic conditions.

From a physical point of view, these local sources act like a thermal capacitor placed in parallel to the thermal model of the LPS28DFW and they can contribute to the local temperature that is different from the environmental temperature.

Depending on the location of the heat sources and the propagation of the heat, we can distinguish the propagation related to different mechanisms as described below.

Convection heat

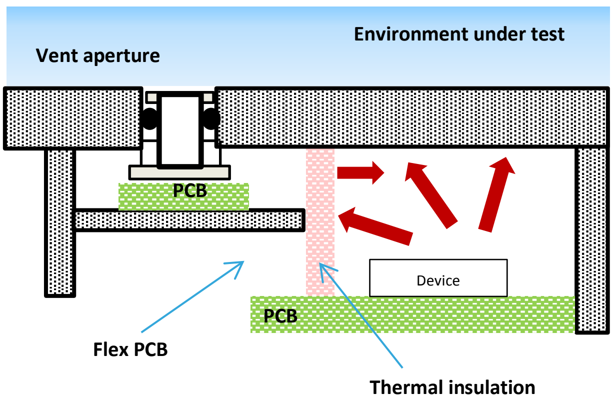
Local thermal sources around the sensor can modify the pressure and temperature measurement by radiating heat.

Typical sources are as follows:

- Other sensors and devices close to the pressure sensor
- Power management devices
- Processors and microcontrollers
- LCD displays that, in particular, provide a significant temperature gradient between the environment and the dead volume inside the system.

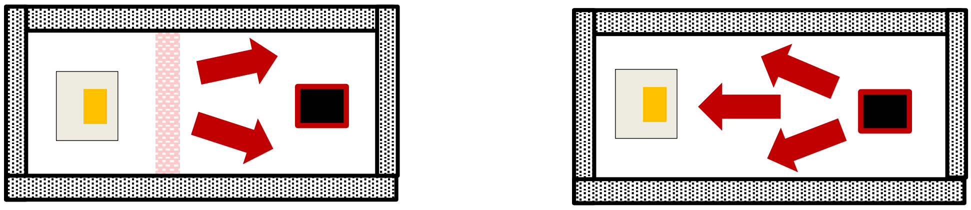
Therefore, the sensor has to be placed at a correct distance from these sources, and to guarantee the appropriate isolation, it is recommended to adopt inside the embodiment, insulation structures as illustrated in Figure 4. Insulation implemented for protecting the sensor from heat. A flexible PCB can be used in order to distance the pressure sensor from the main board and put the LPS28DFW as close as possible to the external environment.

Figure 4. **Insulation implemented for protecting the sensor from heat**



Looking at a section of the sensor housing, Figure 5 shows on the left a correct design with insulation from heat. The heat source is far from the sensor and a thermal protection structure is placed in the middle. On the right, a wrong design is shown as an example without a structure to insulate the sensor from the radiant heat coming from the component nearby.

Figure 5. Top view of the sensor housing: on the left a correct design with thermal insulation, on the right a wrong design



The solution of a cooling channel is not applicable in the case of water-resistant applications. It is important to underline that the LPS28DFW has an embedded quadratic compensation that allows minimizing the effect of temperature in the pressure measurement. In this context, the recommended design is just to introduce a thermal insulation layer but without a cooling channel.

Conduction heat

Thermal conduction mostly occurs through the metal lines on the PCB and PCB itself.

In order to reduce this effect, we recommend adopting thin metal lines around the sensor, at an appropriate distance from the sensor and potential heat sources, avoiding metal areas near and under the device.

A good design rule is provided in Figure 6. Good example of sensor placement on the PCB to get the appropriate isolation from heat sources as an example of a good design, illustrating on the left the positioning of the devices generating heat placed as far as possible from the sensor.

Figure 6. Good example of sensor placement on the PCB to get the appropriate isolation from heat sources

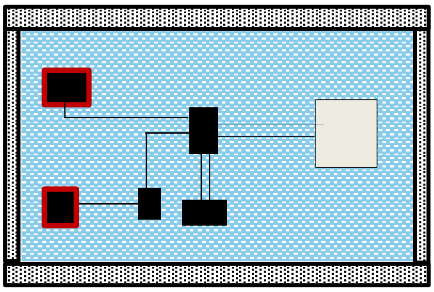
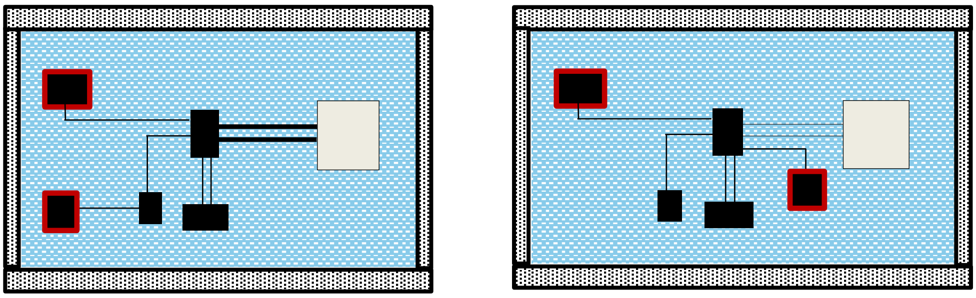


Figure 7. Bad example of sensor wiring on the PCB and incorrect placement of the sensor



In Figure 7, the left graphic of the example shows the wrong size of metal lines that have been used. The bigger dimensions provide a higher level of heat conduction. On the right, the incorrect placement of the sensor, close to a device generating too much heating deteriorates the performance of the sensor. In both cases of thermal propagation, the infrared-based thermal analysis of the whole system, running under different operating conditions, is the right approach for identifying the appropriate placement of the sensor.

2.1.4 Mechanical stress

The placement of the sensor shall avoid any mechanical force applied to the sensor, either directly due to an incorrectly designed mechanical system or manufacturing tolerances or indirectly due to user interaction with the system as in the case of a wearable or portable device.

In other words, the final assembly must be free of hard shearing contact between the LPS28DFW and the cylinder of the housing.

Figure 8. Bad configuration for mechanical stress

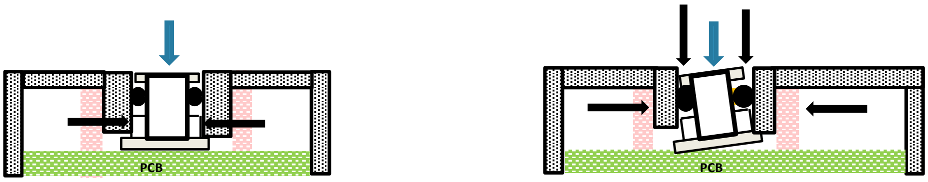
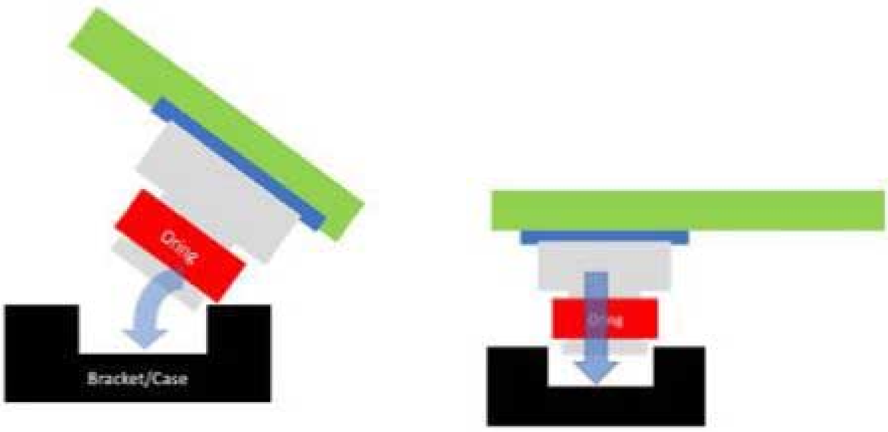


Figure 8 above shows incorrect integration cases where the embodiment structure is directly in contact with the sensor package causing mechanical stress that can deteriorate the performance of the sensor. Thus a minimal clearance has to be maintained to avoid any force applied to the sensor by considering manufacturing tolerances.

Mechanical stress should be also considered when the sensor is assembled in the final application. When the sensor is assembled, it is recommended to position the sensor perpendicularly to avoid any mechanical stress during assembly. The following figure shows a simple example.

Figure 9. Example of sensor assembly inside of final application



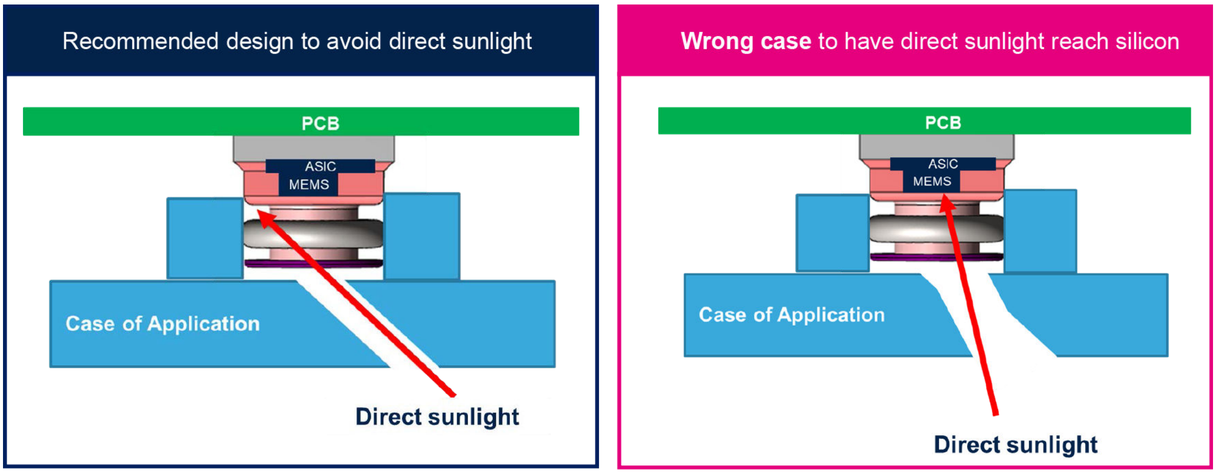
Incorrect way to assemble

Correct way to assemble

2.1.5 Light exposure

Direct exposure of the sensor to light shall be avoided. Sources of direct light (from the sun, a halogen lamp, and so forth) on the sensor might cause a high offset of the pressure value or malfunction because the materials in the device are sensitive to light. We recommend that the mechanical design of the application avoid direct light, refer to the example of a correct design on the left in the following figure.

Figure 10. Example of recommended design to avoid direct light

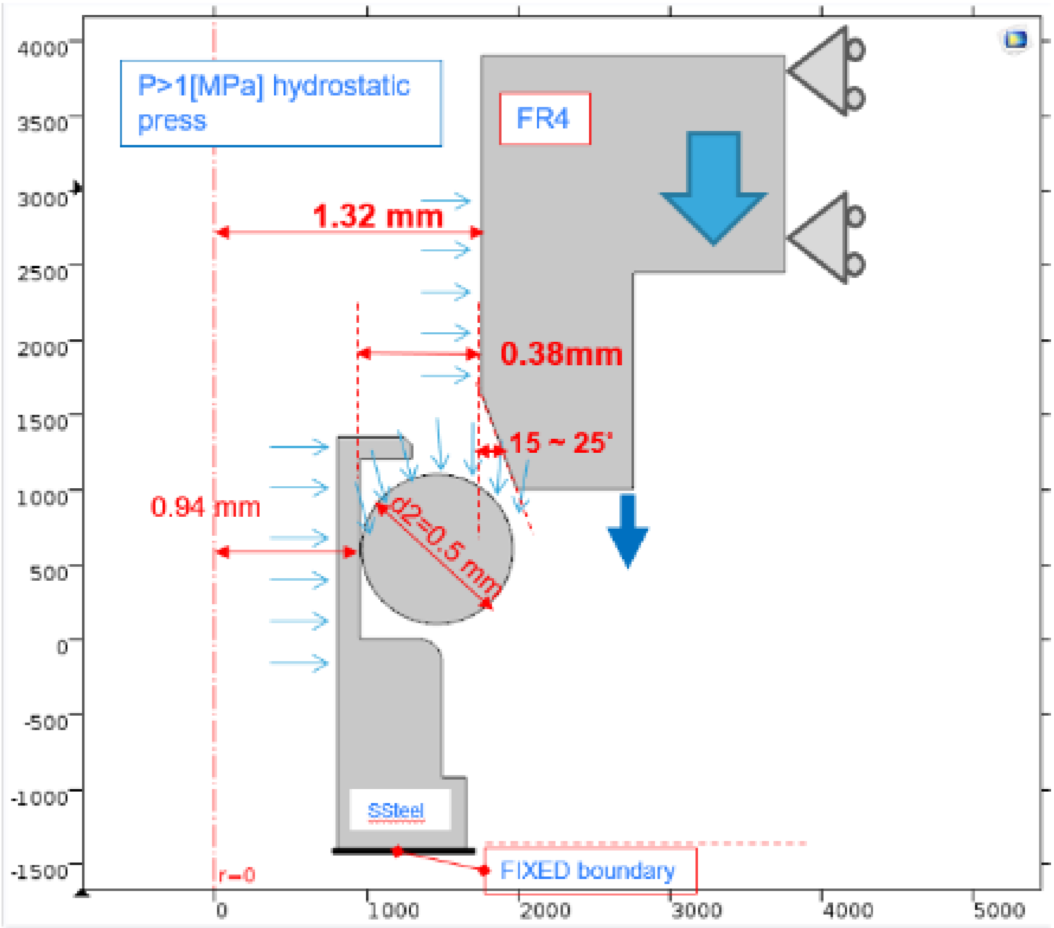


2.2 Sensor embodiment and housing

The sensor housing in the system shall match as much as possible the recommendations previously highlighted for the sensor placement.

The following guideline of the housing dimensions according to the LPS28DFW mechanical dimensions supports 10 bar water pressure proofing and minimizes the mechanical damage to the sensor during assembly or after assembly.

Figure 11. **Example of good sensor embodiment and housing**

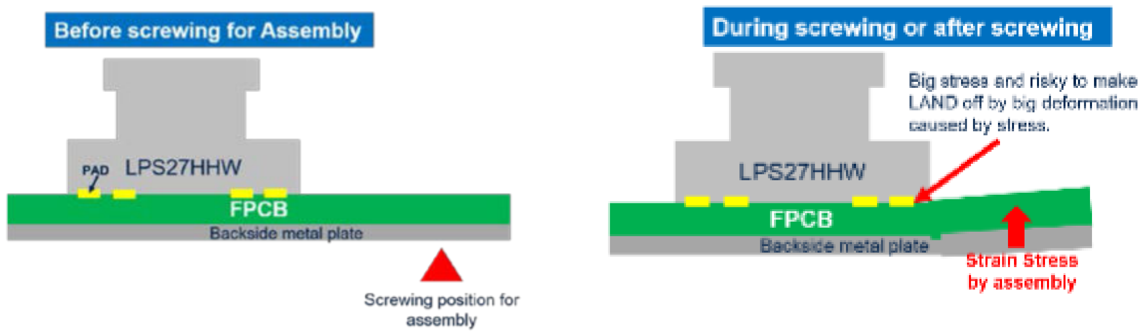


However, it is a reference for one example and the housing design can be optimized depending on the mechanical design of the target application. The sensor's mechanical dimensions and O-ring selection must be considered accordingly.

Furthermore, in case the sensor on the FPCB module is tightened by screws during assembly in the final application, it needs to be done carefully to avoid strain and stress on the FPCB. If not, this could cause the land pad to move off the sensor package which can be caused by strain and stress on the FPCB as shown in Figure 12 below.

A thicker metal plate behind the FPCB can be helpful to reduce the strain and stress on the FPCB or a mechanical design of the housing might be needed to avoid tightening the sensor module with screws.

Figure 12. **Example of strain and stress to PCB during assembly**



(a) **No strain or stress before screwing for assembly** **(b)** **Strain and stress from screwing to impact land**

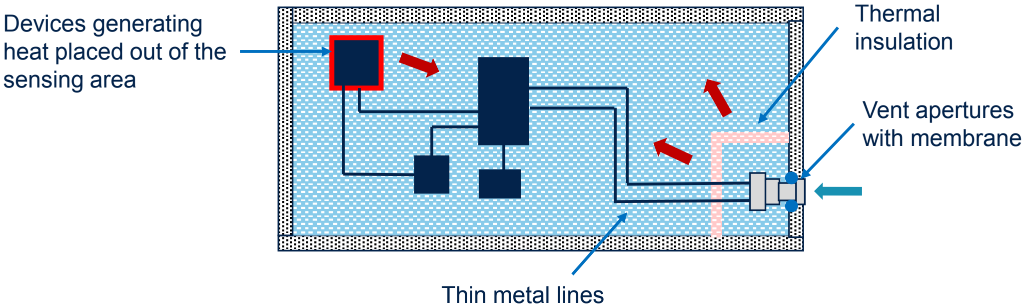
2.3 Sensor protection

An optional filter can be adopted in order to protect the sensor from dust or chemical solvent in the presence of a harsh environment. The key parameter for this kind of implementation is the appropriate choice of the membrane according to the customer design requirements and taking into account that the membrane material may cause a slower response time, in particular in terms of pressure response time.

3 Reference design: integration and housing on a portable device

The example below describes how the placement of the sensor is implemented by following the basic rules described in this document; in other words, by mounting the sensor as far as possible from the main sources of heat present on the board like the display LDO and microcontroller that represent the more critical heat sources. Figure 13. Integration of the LPS28DFW in a sensor chamber with vent apertures illustrates the integration of the sensor in a sensor chamber insulated from heat and with one vent aperture sealed by an O-ring.

Figure 13. Integration of the LPS28DFW in a sensor chamber with vent apertures

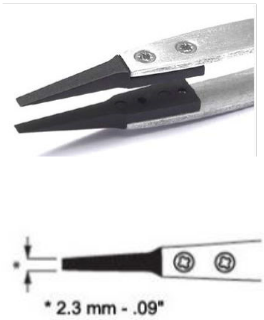


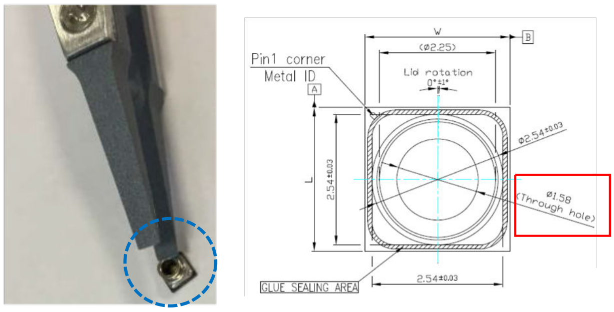
4 Handling tip

Considering the package structure of LPS28DFW, it is strongly recommended to use a plastic wide-tip tweezer to handle the device during evaluation in the lab or production in the customer's manufacturing facility. A tweezer with a recommended tip width of 2.3 mm needs to be used to avoid mechanical damage to the inside of the device during handling and use in production at the customer's site as well.

The recommended tweezer dimension is indicated in the following figure, along with the LPS28DFW package dimensions.

Figure 14. Recommended use of tweezers to avoid mechanical stress to LPS28DFW during handling





Recommended tweezer tip dimension

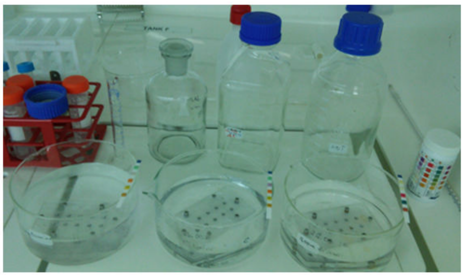
❖ **Tip cannot enter through-hole to touch or damage device**

5 Robustness to corrosive agents

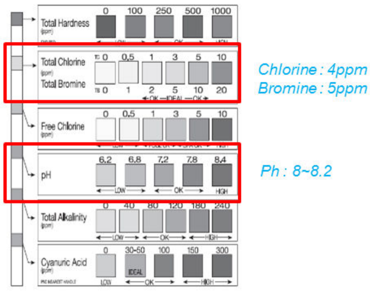
The LPS28DFW was evaluated against swimming pool and sea water to be similar to the applicative scenario. Hot chlorine, bromine, and salt water tests were run on the LPS28DFW which showed high stability, with no impact on accuracy or other performance issues (see Figure 15). Specifically, the testing protocol was 34 cycles (34 days) where each cycle was composed of an immersion for 6 hours in each water condition and the next 18 hours dried in a climatic chamber @ 60 °C, 60% rH.

Further tests with detergent water (commercial shampoo, hand soap) were performed, demonstrating the robustness of the LPS28DFW to these kinds of potential corrosive agents as well.

Figure 15. Chlorine, bromine, saltwater and detergent tests

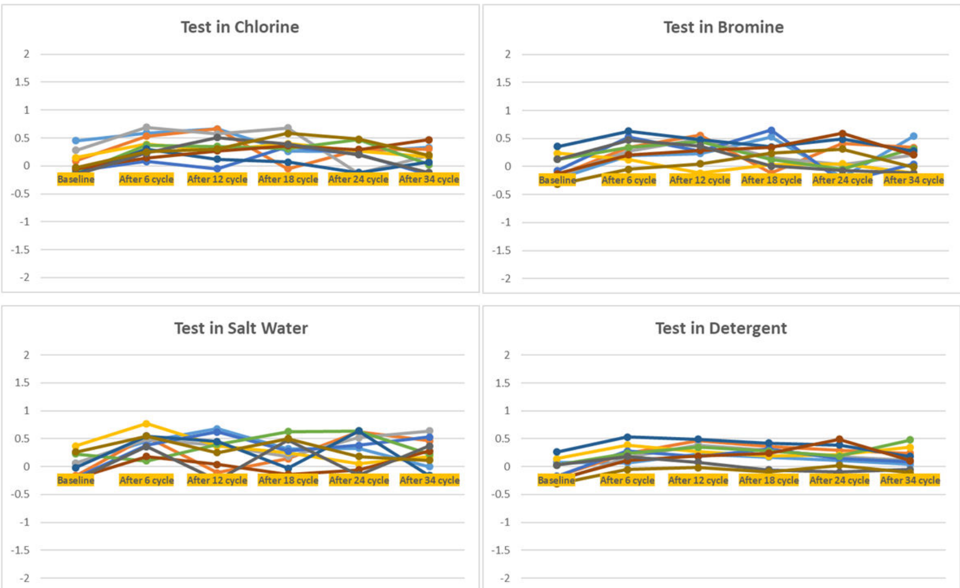


❖ Test under each bottle of Chlorine , Bromine and Salt water



❖ Aqua check strip & measurement scale

❖ Test strip using to confirm test condition.



6 Robustness to high air overpressure stress tests

The LPS28DFW was submitted to 40 test cycles where each cycle was 10 minutes at 10 bar air overpressure and 10 minutes of ambient pressure, and the device demonstrated robustness under these particular conditions. Devices under test were immersed in water during tests in order to observe potential leakage as bubble formations (Figure 16). Further tests were run on the water resistance specification (15 bar) and again the device showed no failures.

Figure 16. LPS28DFW immersed in water for air overpressure

Revision history

Table 1. Document revision history

Date	Version	Changes
22-Feb-2023	1	Initial release

Contents

List of figures